LECTURES ON PROPAGATION

A PRELIMINARY INVESTIGATION OF RADIO TRANSMISSION CONDITIONS OVER LAND AND SEA ON CENTIMETRE WAVELENGTHS

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(ABSTRACT *of a lecture delivered at the* RADIOLOCATION CONVENTION *27th March*, 1946.)

Papers already presented at this Convention have surveyed both the circumstances that gave rise to, and the steps that were taken to implement, a detailed and systematic investigation of the mode of propagation of radio waves within the centimetre wavelength band. The present contribution surveys from a somewhat different standpoint the analysis of the data obtained in some of the investigations described by Megaw. The results of this analysis provide some of the essential basic information which the engineer designing either a radiolocation system or a communication link requires in order that he may assess in advance the performance and reliability of the service to be expected under a variety of conditions.

OVERLAND TRANSMISSIONS

The overland path along which radio transmission has been studied lies between Haslemere, Surrey, and Wembley, Middlesex.† This path is 61 km (38 miles) long, and is quasi-optical, the obstruction of the radio waves by some buildings and trees at the Wembley end being apparently responsible for a general reduction of at least 25 db in the field strength recorded at the frequency used of 3 260 Mc/s (wavelength 9·2 cm). As a result, the maximum input signal received at Wembley is seldom greater than 32 db above 1 μV, whereas in the absence of the obstacles mentioned the maximum value could be 6 db above the free-space signal of 52 db above 1 μV.

The mean daily value of the received signal for the two and a half years ended December 1945, has varied somewhat erratically from a maximum of about 25 db above 1 μV during the summer months, July to September, to a minimum of 16 db or so above 1 μV during the winter months of December to February. This seasonal change is illustrated in Fig. 1, which shows the proportion of time the signal was above the levels of 16, 20 and 24 db above 1 μV on each of the days in the typical summer and winter months indicated. Such a representation of the measured signal strength serves to indicate the quality of the radio circuit being studied, and the communication engineer can decide from this type of information what signal level he can expect to obtain for summer and winter conditions respectively.

A somewhat closer study of the received signal level shows that the mean hourly intensity is sometimes steady to within 1 or 2 db all day, while on other occasions there is a marked diurnal variation ranging from a minimum in the morning to a peak in the late evening at or near midnight. These night-time peaks, which may sometimes have instantaneous values of as much as 15 db above the mean level for the day, are frequently associated with conditions of cloudless sky and absence of wind, known as radiation nights, during which the earth heated by the sun's radiation in daylight is cooling rapidly and giving rise to a condition of temperature inversion at a small height above its surface. When the atmospheric humidity conditions during such a cooling process are appropriate, fog may set in early on the following morning, and this usually has the effect of counteracting the rise in signal strength and causing a considerable decrease to a well-marked minimum value, prior to its recovery

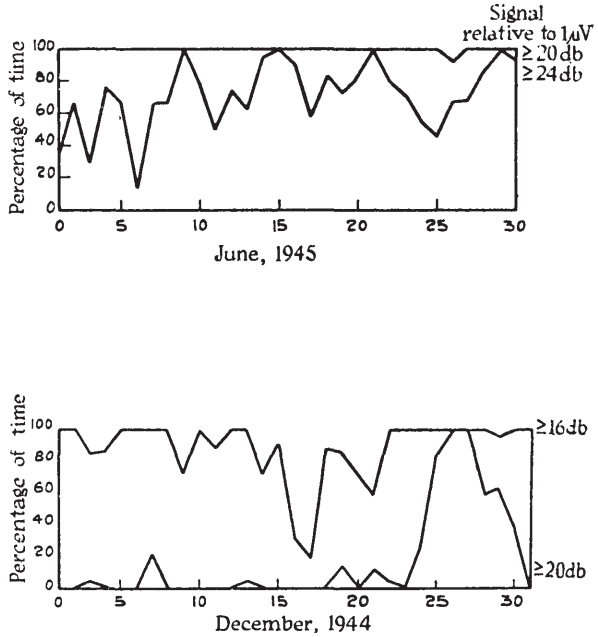

Fig. 1.—Illustrating the seasonal change in reception of signals on 9·2 cm wavelength.

to the normal daily value of signal level as the fog clears. These conditions are illustrated in Fig. 20 of Megaw's paper. On some occasions during the prevalence of fog, and for a duration of less than 0·1% of the total time of recording, the signal has been reduced to the noise level of about 1 μV input to the receiver.

OVERSEA TRANSMISSION

General Radio Results Obtained.

The investigation of radio propagation conditions over sea with which this paper is concerned was carried out in the Irish Sea over the paths indicated in Fig. 3 of Megaw's paper. The two transmitting stations (A and B) at high and low level respectively are situated in South Wales, while the corresponding receiving stations are C and D in North Wales. The frequency used was 3 260 Mc/s (wavelength 9·2 cm) and the radio transmitting, receiving and measuring equipment was substantially similar to that used in the overland studies, and described in some detail by Megaw. In discussing the analysis of the field strength records obtained over the various paths, it is sometimes convenient to refer all signal levels at the input to the receiver to the theoretical free-space values of about 50 db above 1 μV for the distance of 92 km (57 miles) across Cardigan Bay.

The general level of the signal obtained during some two years' observations has ranged from approximately free-space value for the link AC, which has a clear line of sight or optical path, to a value of some 35 to 40 db below the free-space figure for the link BD, for which the distance between transmitter and receiver is about 2·5 times the optical range. In addition

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† See Fig. 3 of Megaw's paper (page 83).

to this decrease in general signal level, the extreme range of variation or fading of the signal increased markedly with reduction in height of the transmission path, typical values of this variation of the mean daily value being about 15 and 50 db for the highest and lowest links respectively.

This result is illustrated in Fig. 2, which is produced from all

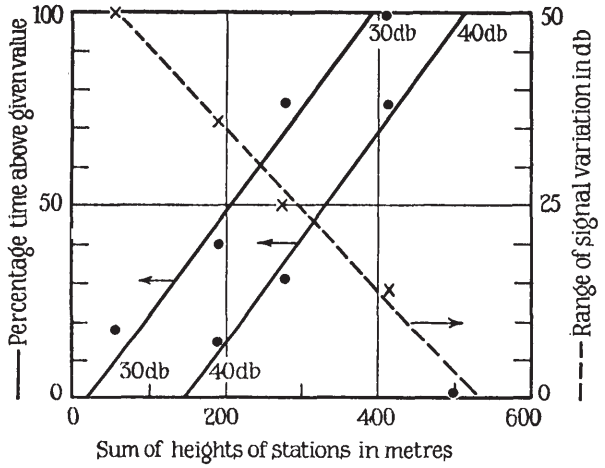

Fig. 2.—Relation between terminal heights of radio stations and period for which the received signal is greater than 30 or 40 db above 1 μV.

the results obtained over the four paths during the period April to September 1944. It will be seen that the percentage of time that the signal level is above the values of 30 and 40 db above 1 μV bears a linear relationship to the sum of the heights of sending and receiving stations. The broken line on the same diagram shows that the range of variation of the signal is inversely proportional to the sum of the heights of the stations. It is thus seen that for the case of radio communication links on centimetre wavelengths operating at or beyond optical range conditions, it is advantageous to place the stations as high as practicable, if the maximum reliability of service is required. On each of the non-optical links, the signal level for some 70 to 80% of the time corresponds to what would have been expected for normal atmospheric-gradient conditions, taking account of both atmospheric refraction and diffraction round the curved surface of the earth.

Comparison with General Meteorological Conditions.

A comparison of the signal intensity records with the general meteorological situation has brought to light certain comparatively well-marked relationships. Among these are the facts that during good weather and the existence of anticyclonic conditions, the signal level is usually high although subject to some variability, especially in summer; while a low signal corresponds to the existence of poor visibility or fog; and a decrease in signal followed by an increase usually occurs at the time of the passage of a front across the path of transmission.

It has been realized for several years on theoretical grounds of the type outlined by Booker,* that the propagation of radio waves in the metre band and below would be markedly dependent upon the vertical gradient of refractive index of the portion of the atmosphere through which the waves travelled. Observations to investigate this subject have been made possible by the use of aircraft flying at various heights along the path of transmission.

Two types of aircraft flight have been undertaken: the first is a horizontal one in which three or four aircraft fly at uniform heights, between about 15 and 500 metres (50 and 1 500 ft), vertically above one another over the whole path between the radio sending and receiving stations; in the second type, one or more aircraft make spiral ascents and descents at fixed points along the path. From the pressure, temperature and humidity observations made during these flights, the gradient of refractive index of the atmosphere, modified to allow for the curvature of the earth, is calculated for comparison with the radio field-strength conditions recorded simultaneously.

With the aid of measurements of the meteorological conditions along the path carried out in the above manner, we can estimate the radio signal intensity to be expected with the aid of theoretical relationship of the type displayed in Fig. 2 of Megaw's paper. This provides a theoretical value of the field intensity for direct comparison with that obtainable from the radio records. The results of such a comparison are presented in Fig. 3, which

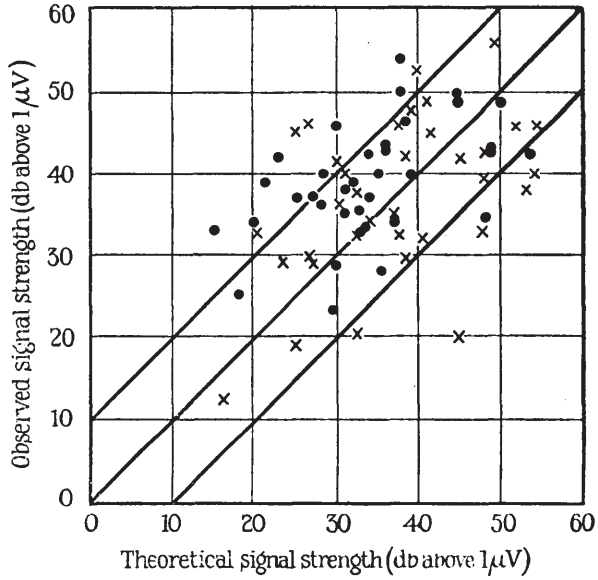

Fig. 3.—Relation between observed signal strengths and those estimated from a refractive index gradient calculated from aircraft observations of temperature and humidity.

summarizes all the observations made during 33 horizontal flights and 34 vertical soundings by the meteorological aircraft flight across Cardigan Bay. It is considered that the overall accuracy of both the meteorological observations and the absolute radio field intensities is such as to justify the introduction of the arbitrary range of $\pm$ 10 db indicated in the diagram as the overall margin of possible error. The agreement between the calculated and observed intensities is seen to be very good, some 70% of the results falling between the limits indicated.

Conclusion

This type of investigation has thus led to the conclusion that the propagation over sea or land of radio waves on frequencies of the order of 3 000 Mc/s is directly associated with the meteorological conditions in the portion of the atmosphere through which the waves travel. Some of the major effects observed in the experiments conducted over sea indicate that the general level of a received radio signal is directly dependent upon the average gradient of atmospheric refractive index over the path in a manner which confirms existing theoretical work on the subject. It has not so far been practicable either to investigate the finer detail of the variations already experienced or to make a special study of conditions under which the gradient of refractive index with height is of the opposite sign to that normally experienced, so giving rise to the abnormal effects particularly at low heights, of the type discussed by Booker. It is also to be noted that the results discussed above

* See page 69.

refer to the conditions experienced in this country: it is likely that markedly different effects will be experienced in other parts of the world where the meteorological conditions are in great contrast to those experienced in Great Britain. Further details of the results of this investigation will be found in a paper read before a Joint Meeting of the Meteorological and Physical Societies in April 1946. It is felt, however, that the results so far obtained and discussed merely touch the fringe of the subject, and a much more detailed and concentrated investigation remains to be conducted before all the phenomena associated with this type of wave propagation are thoroughly understood.

ACKNOWLEDGMENTS

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